CHAPTER 3

AIRCRAFT FABRIC COVERING

AIRCRAFT FABRICS

General

Most aircraft in production today are of all-metal construction. However, many aircraft in service still use fabric for covering wings, fuselages, and control surfaces. In the United States cotton fabrics have long been the standard material for covering aircraft. Cotton fabrics are still used, but other fabrics, such as linen, Dacron, and fiber glass, are gaining in popularity.

Organic and synthetic fibers are used in the manufacture of fabrics or cloth for covering aircraft. The organic fibers include cotton and linen; the synthetic fibers include fiber glass and heat-shrinkable synthetic fibers.

Three of the most common heat-shrinkable synthetic fibers available are a polyamide, manufactured and marketed under the trade name Nylon; an acrylic fiber called Orlon; and a polyester fiber known as Dacron.

Fabric Quality and Strength Requirements

In the original manufacture of a fabric-covered aircraft, the quality and strength of the fabric, surface tape, lacing cord, thread, etc., are determined by the aircraft's never-exceed speed and the pounds per square foot of wing loading. The never-exceed speed for a particular aircraft is that safe speed beyond which it should never be operated. The aircraft wing loading is determined by dividing its total wing planform area (in square feet) into the maximum allowable gross weight.

All fabric, surface tape, reinforcing tape, machine thread, lacing cord, etc., used for re-covering or repairing an aircraft's cover should be of high-grade aircraft textile material. The materials must also be at least as good a quality and of equivalent strength as those originally used by the aircraft manufacturer.

Acceptable fabrics for covering wings, control surfaces, and fuselages are listed in figures 3–1 and 3–2. Fabrics conforming to AMS (Aeronautical Material Specifications), incorporate a continuous marking of specification numbers along the selvage edges to permit identification of the fabric in the field.

The following definitions are presented to simplify the discussion of fabrics. Some of these terms are shown graphically in figure 3–3.

(1) **Warp**—The direction along the length of fabric.
(2) **Warp ends**—The woven threads that run the length of the fabric.
(3) **Filling, woof, or weft**—The direction across the width of the fabric.
(4) **Count**—The number of threads per inch in warp or filling.
(5) **Ply**—The number of yards making up a thread.
(6) **Bias**—A cut, fold, or seam made diagonally to the warp or fill threads.
(7) **Calendering**—The process of ironing fabric by threading it wet between a series of hot and cold rollers to produce a smooth finish.
(8) **Mercerization**—The process of dipping cotton yarn or fabric in a hot solution of diluted caustic soda. This treatment causes the material to shrink and acquire greater strength and luster.
(9) **Sizing**—Material, such as starch, used to stiffen the yarns for ease in weaving the cloth.
(10) **Pinked edge**—An edge which has been cut by machine or shears in a continuous series of V's to prevent raveling.
(11) **Selvage edge**—An edge of cloth, tape, or webbing woven to prevent raveling.

Cotton Fabrics

Grade A airplane cloth is a 4-oz. mercerized fabric made of high-grade, long-staple cotton. It is calendered to reduce the thickness and lay the nap so that the surface will be smooth. There are from 80 to 84 threads per in., warp and fill. The minimum tensile strength is 80 lbs. per in. of width,

Materials	Specification	Minimum tensile strength new (undoped)	Minimum tearing strength new (undoped)	Minimum tensile strength deteriorated (undoped)	Thread count per inch	Use and remarks
Airplane cloth mercerized cotton (Grade "A").	Society Automotive Engineers AMS 3806 (TSO-C15 references this spec.).	80 pounds per inch warp and fill.	5 pounds warp and fill.	56 pounds per inch.	80 minimum, 84 maximum warp and fill.	For use on all aircraft. Required on aircraft with wing loadings greater than 9 p.s.f. Required on aircraft with placarded never-exceed speed greater than 160 m.p.h.
"	MIL-C-5646	"	"	"	"	Alternate to AMS 3806.
Airplane cloth cellulose nitrate predoped.	MIL-C-5643	"	"	"	"	Alternate to MIL-C-5646 or AMS 3806 (undoped). Finish with cellulose nitrate dope.
Airplane cloth cellulose acetate butyrate, predoped.	MIL-C-5642	"	"	"	"	Alternate to MIL-C-5646 or AMS 3806 (undoped). Finish with cellulose acetate butyrate dope.
Airplane cloth mercerized cotton.	Society Automotive Engineers AMS 3804 (TSO-C14 references this spec.).	65 pounds per inch warp and fill.	4 pounds warp and fill.	46 pounds per inch.	80 minimum, 94 maximum warp and fill.	For use on aircraft with wing loadings of 9 p.s.f. or less, provided never-exceed speed is 160 m.p.h. or less.
Airplane cloth mercerized cotton.	Society Automotive Engineers AMS 3802.	50 pounds per inch warp and fill.	3 pounds warp and fill	35 pounds per inch.	110 maximum warp and fill.	For use on gliders with wing loading of 8 p.s.f. or less, provided the placarded never-exceed speed is 135 m.p.h. or less.
Glider fabric cotton.	A.A.F. No. 16128. AMS 3802.	55 pounds per inch warp and fill.	4 pounds warp and fill.	39 pounds per inch.	80 minimum warp and fill.	Alternate to AMS 3802-A.
Aircraft linen	British 7F1					This material meets the minimum strength requirements of TSO-C15.

Figure 3–1. Textile fabrics used in covering aircraft.

Materials	Specification	Yarn Size	Minimum tensile strength	Yards per pound	Use and remarks
Reinforcing tape, cotton.	MIL-T-5661	....	150 pounds per one-half-inch width	....	Used as reinforcing tape on fabric and under rib lacing cord. Strength of other widths approx. in proportion.
Lacing cord, pre-waxed braided cotton.	MIL-C-5649	....	80 pounds double.	310 minimum.	Lacing fabric to structures. Unless already waxed, must be lightly waxed before using.
Lacing cord, special cotton.	U.S. Army No. 6-27.	20/3/3/3	85 pounds double.	....	"
Lacing cord, braided cotton.	MIL-C-5648	....	80 pounds single.	170 minimum.	"
Lacing cord thread; linen and linen hemp.	MIL-T-6779	9 ply 11 ply	59 pounds single. 70 pounds single.	620 minimum. 510 minimum.	"
Lacing cord thread; high-tenacity cotton.	MIL-T-5660	Ticket No. 10.	62 pounds single.	480 minimum.	"
Machine thread cotton.	Federal V-T-276b.	20/4 ply	5 pounds single	5,000 normal.	Use for all machine sewing.
Hand sewing thread cotton.	V-T-276b. Type III B.	8/4 ply	14 pounds single.	1,650 normal.	Use for all hand sewing. Use fully waxed thread.
Surface tape cotton (made from AN-C-121).	MIL-T-5083	....	80 lbs/in.	....	Use over seams, leading edges, trailing edges, outer edges and ribs, pinked, scalloped or straight edges.
Surface tape cotton.	Same as fabric used.	....	Same as fabric used.	....	Alternate to MIL-T-5083.

FIGURE 3-2. Miscellaneous textile materials.

warp and fill. The term "4 ounce" indicates that the normal weight of the finished cloth is 4 oz./sq. yd. for 36- and 42-in. widths. Fabric of this grade and weight is acceptable for covering any aircraft fabric surface.

Linen Fabrics

Unbleached linen fabric is used extensively in England and to a limited degree in the United States. This fabric is practically identical to Grade

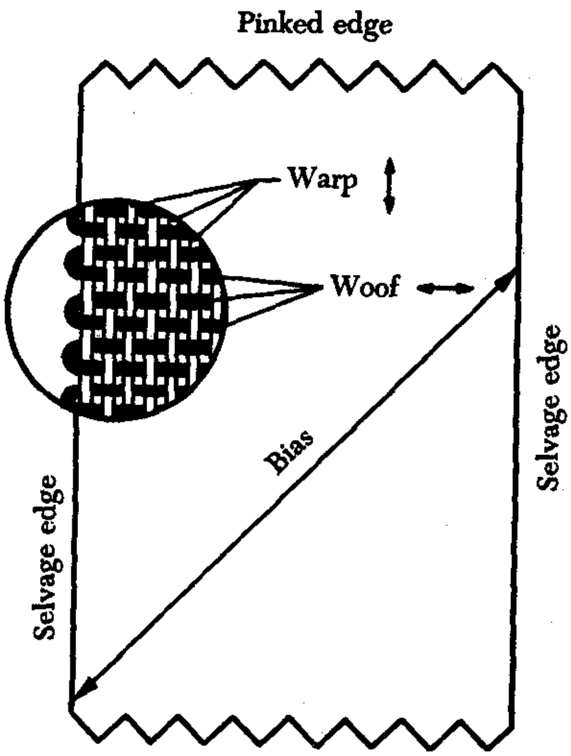


FIGURE 3–3. Fabric terms.

A cotton fabric insofar as weight, strength, and threads per inch are concerned.

Dacron Fabrics

Dacron is a very smooth monofilament, polyester fiber manufactured by the condensation of dimethyl terephthalate and ethylene glycol. A generally standard style and weight of Dacron cloth has evolved for use as aircraft covering. It is a plain weave with a weight of about 3.7 oz./sq. yd. This heavy-duty fabric has a tensile strength of approximately 148 lbs./in. and can be used to replace Grade A cotton and linen fabrics.

A fine weave, medium weight Dacron fabric is used when a minimum covering weight and a very smooth finish are desired. The medium weight fabric has a tensile strength of approximately 96 lbs./in., weighs about 2.7 oz./sq. yd., and can also be used as a replacement for Grade A cotton fabric.

Glass Cloth

Glass cloth, or fiber glass cloth, is made from fine-spun glass filaments which are woven into a strong, tough fabric. Glass cloth used for aircraft covering has a plain weave and weighs about 4.5 oz./sq. yd.

Glass cloth is not affected by moisture, mildew, chemicals, or acids. It is also fire resistant.

Glass cloth applications generally fall into the following classes:

(1) Class A is a complete or partial reinforcement of a serviceable fabric covering. No direct structural attachment of the glass cloth is provided. This composite covering is considered airworthy until the underlying conventional fabric deteriorates below the values listed in figure 3–1.

(2) Class B is a reinforcement of a fabric covering wherein the glass cloth is provided with the same direct structural attachment as that used with the original covering. This composite covering is considered airworthy until the underlying conventional fabric has deteriorated to a strength less than 50% of the minimum tensile strength values for new fabric listed in figure 3–1.

(3) Class C is replacement coverings applied either independently or over a conventional covering. The glass covering should possess all the necessary characteristics for airworthiness and is in no way dependent upon the underlying covering if one is present.

MISCELLANEOUS TEXTILE MATERIALS

Surface Tape

Surface tape is the finishing tape that is doped over each rib or seam to cover the stitching and provides a neat, smooth, finished appearance. It can be obtained with serrated or pinked edges, or with a straightedge impregnated with a sealing compound. The compound-impregnated edges or pinked edges provide better adhesion to the fabric covering.

Surface tape is made from Grade A fabric in various widths from 1¼ to 5″ and from glider fabric in 1½ and 6″ widths. Cotton surface tape may be used with Grade A cotton, linen, or Dacron fabric. Surface tape is also available in Dacron fabric, which should be the first choice when covering an aircraft with Dacron fabric. Linen surface tape frequently is used with fiber glass covering, especially for covering screwheads. If fiber glass tape is used, it is difficult to remove the irregularities caused by the screwheads. Using linen tape to cover screwheads gives a smooth, finished appearance.

Surface tape or finishing tape should be placed over all lacing, seams (both machine- and hand-sewn), corners, edges, and places where wear is likely to occur. Two-inch tape generally is used for this purpose. Pinked surface tape is sometimes applied over the trailing edges of control surfaces and airfoils. For such application the tape must be at least 3 inches in width and if the aircraft "never-exceed speed" is greater than 200 mph, notch the tape at equal intervals not to exceed 18" between notches. Notching of trailing edge is unnecessary if the never exceed speed is under 200 mph. If the tape begins to separate from the trailing edge, it will tear at a notched section and thereby prevent loosening of the entire strip.

Tape is applied over a second wet coat of dope which is applied after the first coat has dried. Another coat of dope is applied immediately over the tape. The tape adheres firmly to the covering because both surfaces of the tape are impregnated with dope.

Reinforcing Tape

Reinforcing tape is used over ribs between the fabric covering and the rib stitching to prevent the stitching cord from cutting through the fabric. It is also used for cross-bracing ribs and for binding. Reinforcing tape is fabricated from cotton, Dacron, fiber glass, or linen materials. A tape made from fiber glass on acetate with a pressure-sensitive adhesive is also available.

Reinforcing tape is available in a variety of widths conforming to the different widths of ribs or rib capstrips. The tape should be slightly wider than the member it covers. A double width is sometimes necessary for very wide members.

Reinforcing tape is used under all lacing to protect the fabric from cuts. This tape should be under a slight tension and secured at both ends. For wings with plywood or metal leading edge covering, the reinforcing tape is extended only to the front spar on the upper and lower surfaces.

Sewing Thread

Thread is made with a right or left twist that is identified by various terms. Machine, machine twist, left twist, or Z-twist indicates a left-twist thread; S-twist indicates a right-twist thread.

An unbleached silk-finish, left-twist cotton thread is used to machine sew cotton fabrics. Silk-finish refers to a thread which has been sized to produce a hard, glazed surface. This finish prevents the thread from fraying and becoming weak. A thread having a tensile strength of at least 5 lbs. per single strand should be used. An unbleached white cotton, silk-finish thread is used in hand sewing cotton fabrics. This thread must have a strength of at least 14 lbs. per single strand.

Dacron fabrics are sewn with Dacron sewing thread. Glass fabrics, when sewn, are sewn with special synthetic threads.

Thread for hand sewing and lacing cord should be waxed lightly before using. The wax should not exceed 20% of the weight of the finished cord. A beeswax free from paraffin should be used for waxing.

Rib Lacing Cord

Rib lacing cord is used to sew the fabric to the ribs. The cord must be strong to transmit the suction on the upper surface of the wing from the fabric to the ribs, which, in turn, carry the load into the main wing structure. The cord must also resist fraying caused by the flexing action of the fabric and wing ribs. Dacron, linen, glass, or cotton cords are used for rib lacing cord.

Special Fasteners

When repairs are made to fabric surfaces attached by special mechanical methods, the original type of fastening should be duplicated. Screws and washers are used on several models of aircraft, and wire clips are used on other models. Screws or clips may not be used unless they were used by the manufacturer of the aircraft. When self-tapping screws are used to attach fabric to metal rib structure, the following procedure should be observed. Worn or distorted holes should be re-drilled, and a screw one size larger than the original should be used as a replacement. The length of the screw should be sufficient so that at least two threads of the grip (threaded part) extend through and beyond the rib capstrip. A thin washer, preferably celluloid, should be used under the heads of screws, and pinked-edge tape should be doped over each screwhead.

SEAMS

A seam consists of a series of stitches joining two or more pieces of material. Properly formed seam stitches possess the following characteristics:

(1) **Strength.** A seam must have sufficient strength to withstand the strain to which it will be subjected. The strength of a seam is affected by the type of stitch and thread used, number of stitches per inch of seam, tightness of the seam, construction of the seam, and the size and type of needle used.

(2) **Elasticity.** The elasticity of the material to be sewed determines the degree of elasticity desirable in a seam. Elasticity is affected by the quality of thread used, tension of the thread, length of stitch, and type of seam.

(3) **Durability.** The durability of a seam is determined by the durability of the material. Tightly woven fabrics are more durable than loosely woven fabrics which tend to work or slide upon each other. For this reason, the stitches must be tight and the thread well set into the material to minimize abrasion and wear caused by contact with external objects.

(4) **Good appearance.** The appearance of a seam is largely controlled by its construction. However, appearance should not be the principal factor when constructing covers. Due consideration must be given to strength, elasticity, and durability.

Sewed Seams

Machine-sewed seams (figure 3–4) should be of the folded-fell or French-fell types. A plain lapped seam is satisfactory where selvage edges or pinked edges are joined.

All machine sewing should have two rows of stitches with 8 to 10 stitches per inch. A lockstitch is preferred. All seams should be as smooth as possible and provide adequate strength. Stitches should be approximately 1/16 in. from the edge of the seam, and from 1/4 to 3/8 in. from the adjacent row of stitches.

Hand sewing is necessary to close the final openings in the covering. Final openings in wooden wing coverings are sometimes closed by tacking, but sewing is preferable. A 1/2-in. hem should be turned under on all seams to be hand sewn. Preparatory to hand sewing, the fabric on wooden wings can be held under tension by tacks; fabric on metal wings can be pinned to adhesive tape pasted to the trailing edge of the wings.

Hand sewing or tacking should begin where machine sewing stops and should continue to the point where machine sewing or uncut fabric is again reached. Hand sewing should be locked at 6-in. intervals and the seams should be properly finished with a lockstitch and a knot (figure 3–5). Where hand sewing or permanent tacking is necessary, the fabric should be so cut that it can be doubled under before it is sewed or permanently tacked. After hand sewing has been completed, the temporary tacks should be removed. In hand sewing there should be a minimum of four stitches per inch.

A double-stitched lap joint should be covered with pinked-edge surface tape at least 4 in. wide.

Spanwise seams on the upper or lower surface should be sewed with a minimum protuberance. The seam should be covered with pinked-edge tape at least 3 in. wide.

A spanwise seam sewed at the trailing edge should be covered with pinked-edge surface tape at least 3 in. wide. Notches (V-shaped) at least 1 in. deep and 1 in. wide should be cut into both edges of the surface tape if it is used to cover spanwise seams on trailing edges, especially the trailing edges of control surfaces. For application on aircraft with never-exceed speed of over 200 mph the tape should be notched at equal intervals not to exceed 18" between notches. If the tape begins to separate because of poor adhesion or other causes, it will tear at a notched section, thus preventing progressive loosening of the entire length of tape.

Sewed seams parallel to the line of flight (chordwise) may be placed over a rib, but the seams should be placed so that the lacing will not be through them.

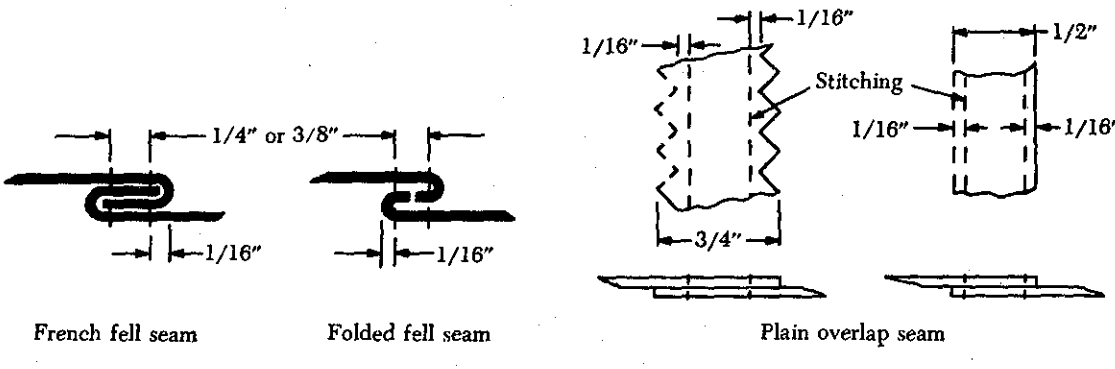


FIGURE 3–4. Machine-sewed seams.

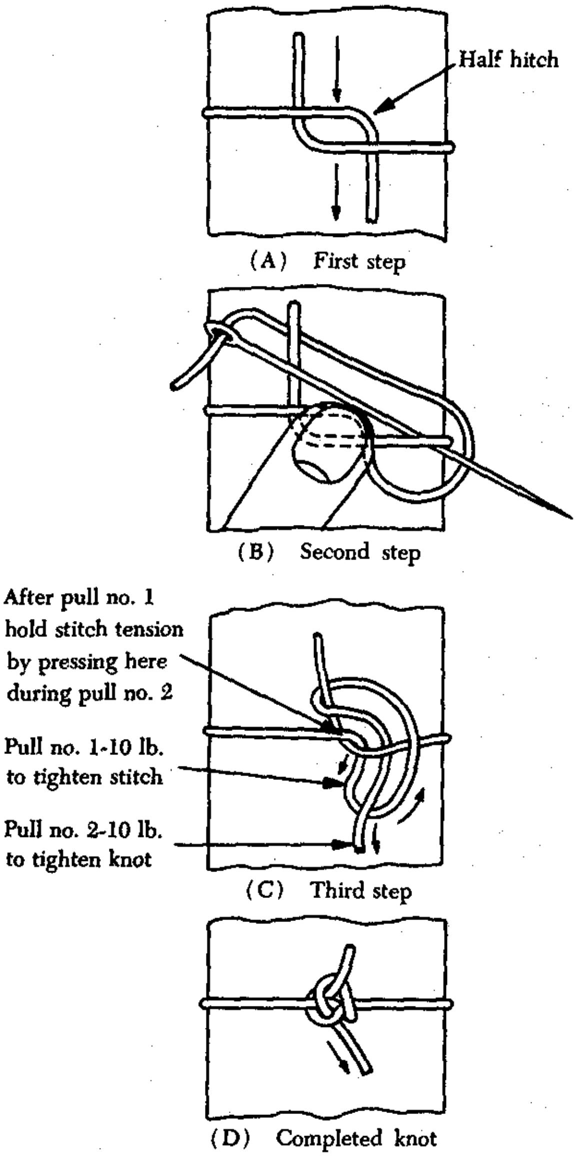


FIGURE 3-5. Standard knot for rib lacing (modified seine knot).

Doped Seams

(1) For a lapped and doped spanwise seam on a metal-or-wood-covered leading edge, lap the fabric at least 4 inches and cover with pinked-edge surface tape at least 4 inches wide.

(2) For a lapped and doped spanwise seam at the trailing edge, lap the fabric at least 4 inches and cover with pinked-edge surface tape at least 3 inches wide.

APPLYING COVERING

General

The proper application of cloth on the surfaces is essential if a good appearance and the greatest strength are to be obtained from the material selected. A good covering job is important not only from a strength and appearance standpoint, but also because it affects the performance of the airplane. All covering must be taut and smooth for best performance.

All fabric materials to be used in covering should be stored in a dry place and protected from direct sunlight until needed. The room in which the sewing and application of the covering is done should be clean and well ventilated.

Preparation of the Structure for Covering

One of the most important items in covering aircraft is proper preparation of the structure. Dope proofing, covering edges which are likely to wear the fabric, preparing plywood surfaces, and similar operations, if properly done, will do much toward ensuring an attractive and long-lasting job.

Dope Proofing

Treat all parts of the structure that come in contact with doped fabric with a protective coating, such as aluminum foil, dope-proof paint, or cellulose tape. Clad aluminum and stainless steel parts need not be dope proofed.

Chafe Points

All points of the structure, such as sharp edges or boltheads, that are likely to chafe or wear the covering should be covered with doped-on fabric strips or taped with cellophane or other nonhygroscopic adhesive tape. After the cover has been installed, the chafe points of the fabric should be reinforced by the doping-on of fabric patches. Where a stronger reinforcement is required, a cotton duck or leather patch should be sewed to the fabric patch and then doped in place. All portions of the fabric pierced by wires, bolts, or other projections should be reinforced. Patches should fit the protruding part as closely as possible to prevent the entrance of moisture or dirt.

Inter-Rib Bracing

A continuous line of reinforcing tape may be used to successively tie the rib sections between the spars together at equally spaced intervals to hold the ribs in correct alignment and prevent their warping. Wing ribs that do not have permanent inter-rib bracing should be tied in position with reinforcing tape. Approximately half way between the front and rear spar, apply the tape diagonally between the top and bottom capstrip of each suc-

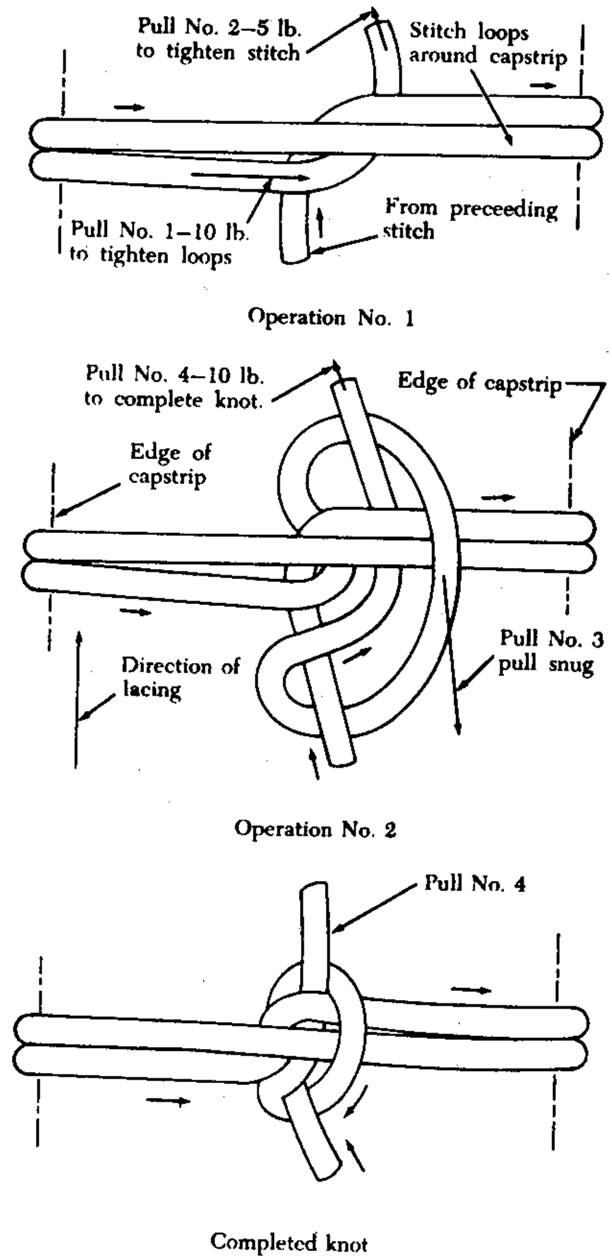


FIGURE 3-6. Standard knot for double loop lacing.

cessive rib from the wing butt rib to the tip rib. Tape is to be continuous and will be anchored with one turn around each individual rib cap strip.

Preparing Plywood Surfaces for Covering

Before covering plywood surfaces with fabric, prepare the surface by cleaning and applying sealer and dope.

Sand all surface areas that have been smeared with glue to expose a clean wood surface. Remove loose deposits such as wood chips and sawdust. Remove oil or grease spots by carefully washing with naphtha.

After cleaning the surfaces, apply one brush coat or two dip coats (wiped) of a dope-proof sealer, such as that conforming to Military Specification MIL–V–6894 thinned to 30% nonvolatile content, and allow to dry 2 to 4 hrs. Finally, before covering, apply two brush coats of clear dope, allowing the first coat of dope to dry approximately 45 min. before applying the second coat.

Covering Practices

The method of fabric attachment should be identical, as far as strength and reliability are concerned, to the method used by the manufacturer of the airplane to be re-covered or repaired. Fabric may be applied so that either the warp or fill threads are parallel to the line of flight. However, it is usually preferable for the warp threads to be parallel to the line of flight. Either the envelope method or blanket method of covering is acceptable.

The envelope method of covering consists of sewing together widths of fabric cut to specified dimensions and machine sewn to form an envelope that can be drawn over the frame. The trailing and outer edges of the covering should be machine sewn unless the component is not favorably shaped for sewing, in which case the fabric should be joined by hand sewing.

In the blanket method of covering, widths of fabrics of sufficient lengths are sewn together to form a blanket over the surfaces of the frame. The trailing and outer edges of the covering should be joined by a plain overthrow or baseball stitch. For airplanes with a placarded never-exceed speed of 150 m.p.h. or less, the blanket may be lapped at least 1 in. and doped to the frame or the blanket; it may be lapped at least 4 in. at the nose of metal- or wood-covered leading edges, doped, and finished with pinked-edge surface tape at least 4 in. wide. In both the envelope and blanket coverings, the fabric should be cut in lengths sufficient to pass completely around the frame, starting at the trailing edge and returning to the trailing edge. Seams parallel to the line of flight are preferable; however, spanwise seams are acceptable.

Before applying cotton or linen fabrics, brush on several coats of clear, full-bodied nitrate dope on all points to which the fabric edges will be cemented. If the structure is not doped, the dope used to cement the fabric edges will be absorbed by the surface as well as by the fabric. This will result in a poor bond to the structure after the dope has dried. Dacron fabric can be attached to the structure by using either nitrate dope or specially formulated cements.

After securing the cover, cotton and linen fabrics may be water-shrunk to remove wrinkles and excess slack. The fabric must be dried thoroughly before doping begins. Dacron may be heat-shrunk by using an electric iron set at 225° F. or by using a reflector heater. Do not apply excessive heat, because the Dacron, as well as the understructures of wood, may be damaged.

Shrinking should be done in several stages on opposite sides to shrink the entire area uniformly. Remove the excess slack with the initial application of heat. The second pass will then shrink the fabric to the desired tautness und remove most of the remaining wrinkles. Nonshrinking nitrate and butyrate dopes are available and produce no further shrinking or tightening. Regular dopes will pull the fibers and strands together and can damage light structures. A nonshrinking dope must be used when Dacron is heat-shrunk to its final tautness.

Taping

Sewed seams, lapped edges, and rib stitching or screws must be covered with pinked-edge surface tape. Use surface tape having the same properties as the fabric used for covering.

Apply the tape by first laying down a wet coat of dope, followed immediately by the tape. Press the tape into the dope. Work out any trapped air and apply a coat of dope over the surface of the tape.

COVERING WINGS

Wings may be covered with fabric by the envelope, blanket, or combination method. The envelope method is preferable and should be used whenever possible.

The envelope method of covering wings consists of sewing together several widths of fabric of definite dimensions and then running a transverse (spanwise) seam to make an envelope or sleeve. The advantage of the envelope method is that practically all sewing is by machine, and there is an enormous saving of labor in fitting the covering. The envelope is pulled over the wing through its open end, which is then closed over the butt by hand sewing. When the envelope is used in repairing a portion of a surface the open end is fitted to extend 3 inches beyond the adjacent rib. If the envelope is of the proper dimensions, it will fit the wing snugly. When possible, the spanwise seam should be placed along the trailing edge.

In the blanket method several widths of fabric are machine sewed together and placed over the wing with a hand-sewed, spanwise seam along the trailing edge. Care must be taken to apply equal tension over the whole surface.

The combination method uses the envelope method as much as possible. and the blanket method on the remainder of the covering. This method is applicable to wings with obstructions or recesses that prevent full application of an envelope.

After the cover is sewn in place and shrunk, reinforcing tape of at least the width of the capstrip is placed over each rib and the fabric is laced to each rib. Except on very thick wings, the rib lacing passes completely around the rib. On thick wings the rib top and bottom cap strips are individually laced. In lacing any covering to a wing, the lacing is held as near as possible to the capstrip, by inserting the needle immediately adjacent to the capstrip. The rib should not have any rough or sharp edges in contact with the lacing, or it will fray and break. Each time the lacing cord goes around the rib it is tied, and the next stitch is made at the specified distance.

In order not to overstress the lacing, it is necessary to space the stitches a definite distance apart, depending on the speed of the airplane. Because of the additional buffeting caused by the propeller slipstream, the stitching must be spaced closer on all ribs included within the propeller slipstream. It is customary to use this closer spacing on the rib just outboard of the propeller diameter as well.

The stitch spacing should not exceed the approved spacing on the original covering of the aircraft. If the spacing cannot be ascertained because of destruction of the covering, acceptable rib stitch spacing may be found in figure 3–7. The lacing holes should be placed as close as possible to the capstrip to minimize the tendency of the cord to tear the fabric. All lacing cord should be lightly waxed with beeswax for protection.

Anti-tear Strips

In very high speed airplanes difficulty is often experienced with rib lacing breaking or with fabric tearing in the slipstream.

On aircraft with never-exceed speeds in excess of 250 m.p.h., anti-tear strips are recommended under reinforcing tape on the upper surface of wings and on the bottom surface of that part of the wing in the slipstream. Where the anti-tear strip is used on both the top and the bottom surfaces, extend it continuously up to and around the leading edges and back to the trailing edge. Where the strip is used only on the top surface, carry it up to and around the leading edge and back on the lower surface as far aft as the front beam or spar. For this purpose the slipstream should be considered as being equal to the propeller diameter, plus one extra rib space on each side. Cut anti-tear strips from the same material as that used for covering, and cut them wide enough to extend beyond the reinforcing tape on each side to engage the lacing cord. Attach the strips by applying dope to that part of the fabric to be covered by the strip and applying dope freely over the strip.

Single-Loop Wing Lacing

Both surfaces of fabric covering on wings and control surfaces should be securely fastened to the ribs by lacing cord or any other method originally approved for the aircraft.

All sharp edges against which the lacing cord may bear must be protected by tape to prevent abrasion of the cord. Separate lengths of lacing cord should be joined by the splice knot shown in figure 3–8. The common square knot, which has a very low slippage resistance, should not be used to splice lengths of cord. The utmost care should be used to assure uniform tension and security of all stitches.

Rib stitching usually is started at the leading edge of the rib and continued to the trailing edge. If the leading edge is covered with plywood or metal, start the lacing immediately aft of these coverings. The first or starting stitch is made with a

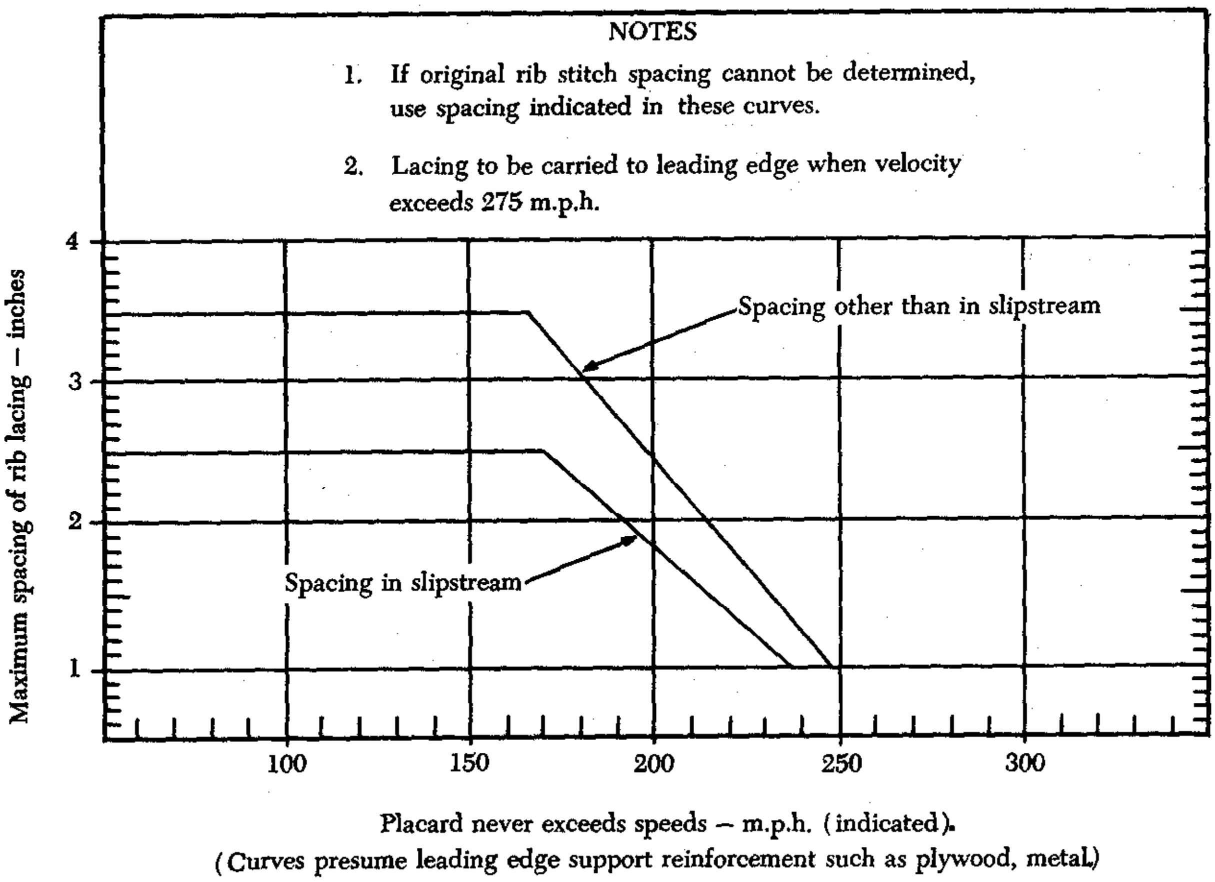
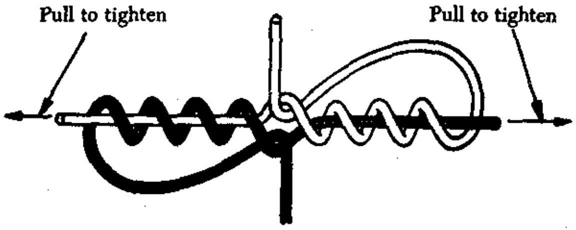
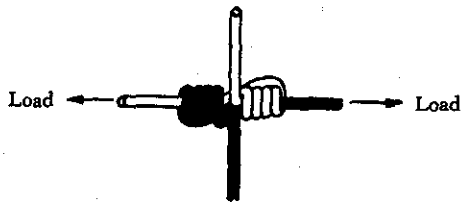


FIGURE 3–7. Rib stitch spacing chart.



Knot formed but not tightened.



Knot completed.

FIGURE 3–8. Splice knot.

double loop, using the method illustrated in figure 3–9. All subsequent stitches can be made with a single loop. The spacing between the starting stitch and the next stitch should be one-half the normal stitch spacing. Where stitching ends, such as at the rear spar and the trailing edge, the last two stitches should be spaced at one-half normal spacing.

Double-Loop Wing Lacing

The double-loop lacing illustrated in figures 3–6 and 3–10 represents a method for obtaining higher strengths than are possible with the standard single lacing. When using the double-loop lacing, make the tie-off knot by the method shown in figure 3–6.

Tie-off Knots

All stitches other than the starting stitch must be tied off using the standard knot (modified seine) for rib lacing Figure 3–5. This knot is placed at the edge of the reinforcing tape Figure 3–9. Knots installed on top of the reinforcing tape are subject to increased wear and also have an adverse effect on the aerodynamics of the airfoil.

Tie-off knots usually are placed on the lower surface of low-wing aircraft and on the top surface of high-wing aircraft, to improve the final appearance of the surfaces.

Final location of the knot depends upon the original location selected by the manufacturer. If such information is not available, consider positioning the knot where it will have the least effect on the aerodynamics of the airfoil.

The seine knot admits a possibility of improper tightening, resulting in a false (slip) form with greatly reduced efficiency and must not be used for last stitch tie-offs. Lock the tie-off knot for the last stitch by an additional half-hitch. Under no circumstances pull tie-off knots back through the lacing holes.

COVERING FUSELAGES

Fuselages are covered by either the sleeve or blanket method, similar to the methods described for covering wings. In the sleeve method several widths of fabric are joined by machine-sewed seams to form a sleeve that will fit snugly when drawn over the end of the fuselage. When the sleeve is in place, all seams should be as nearly parallel as possible to the longitudinal members of the fuselage.

In the blanket method all seams are machine sewed, except one final longitudinal seam along the bottom center of the fuselage. In some cases the blanket is put on it two or three sections and hand sewed on the fuselage. All seams should run fore and aft.

Fuselage Lacing

Fabric lacing is also necessary on deep fuselages and on those where former strips and ribs shape the fabric to a curvature. In the latter case the fabric should be laced to the formers at intervals. The method of attaching the fabric to the fuselage should be at least the equivalent in strength and reliability to that used by the manufacturer of the airplane.

VENTILATION, DRAIN, AND INSPECTION OPENINGS

The interior of covered sections is ventilated and drained to prevent moisture from accumulating and damaging the structure. Ventilation and drainage holes are provided and the edges reinforced with plastic, aluminum, or brass grommets.

Grommets are doped to the underside of fabric

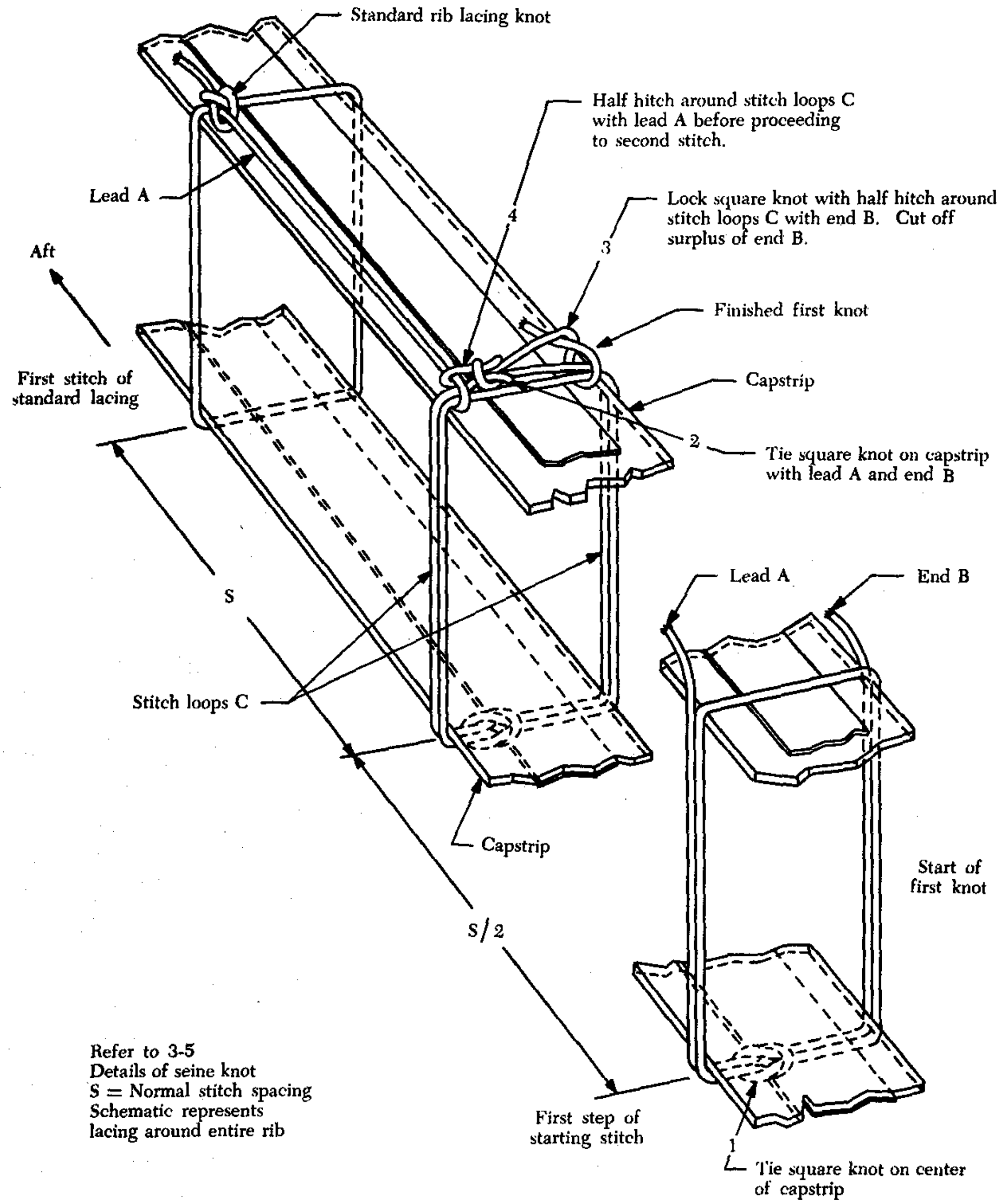


FIGURE 3-9. Starting stitch for rib lacing.

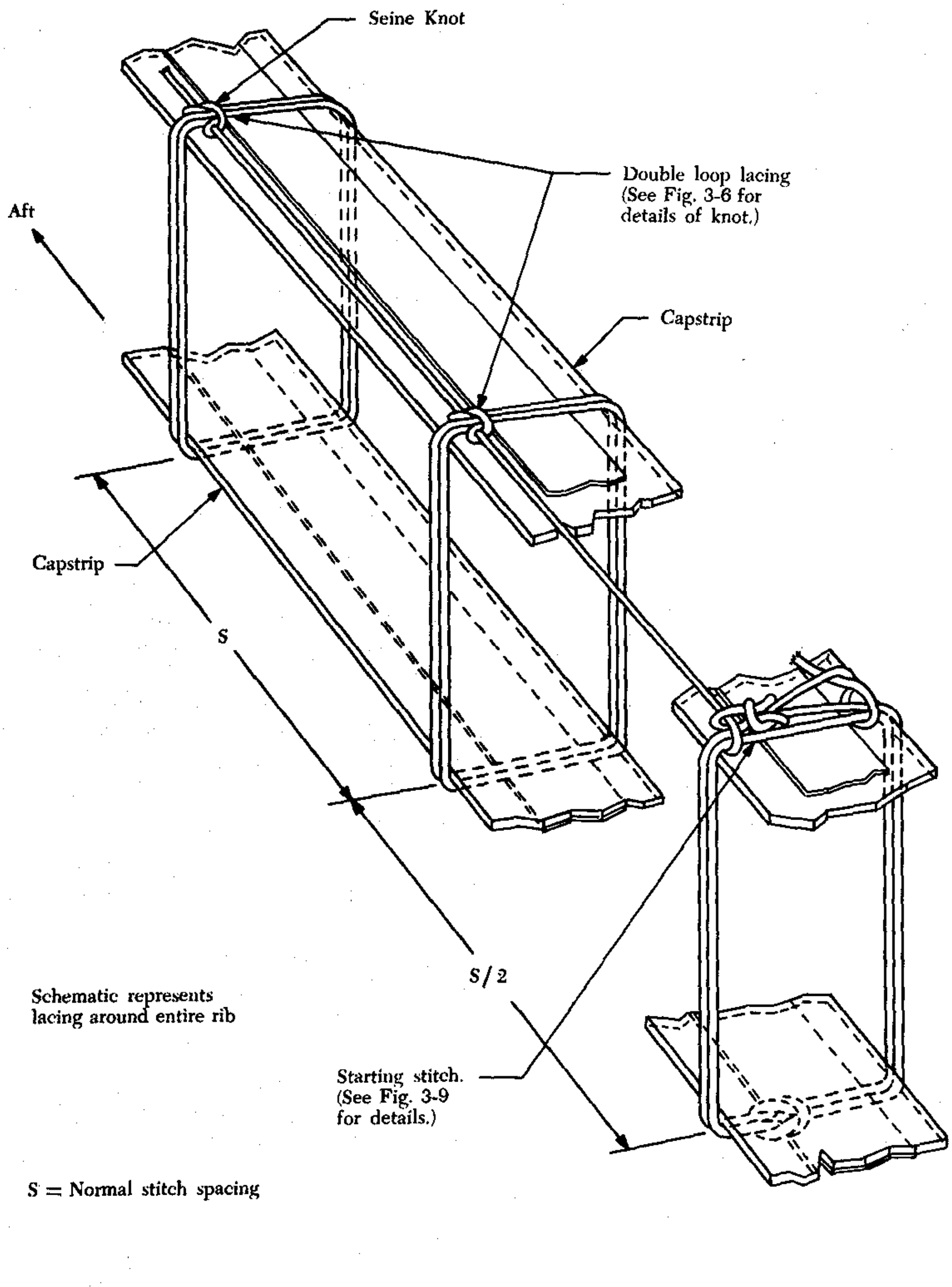


FIGURE 3–10. Standard double-loop lacing.

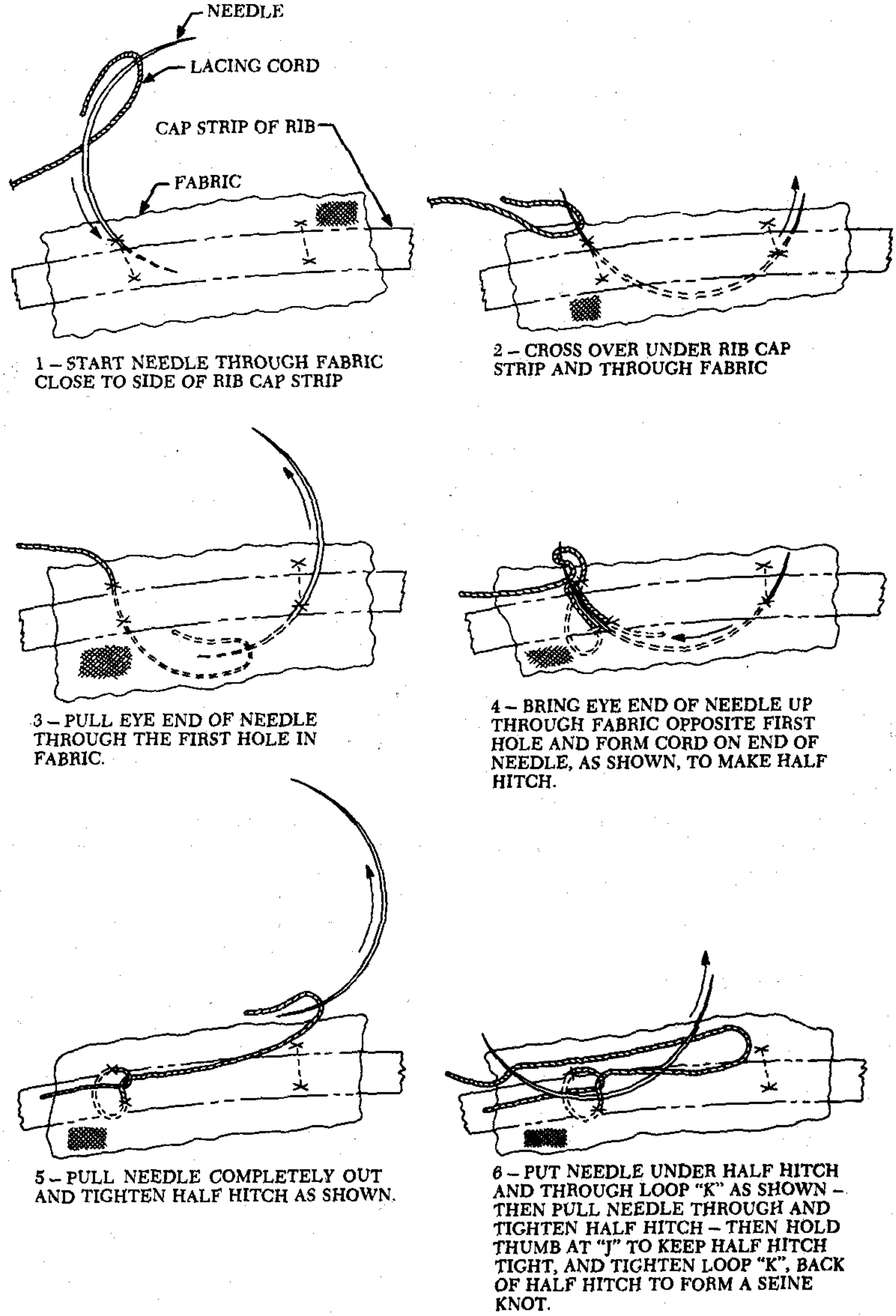


FIGURE 3-11. Rib lacing around capstrip.

surfaces wherever moisture may be trapped. It is customary to place one of these grommets on each side of a rib on the underside at the trailing edge. The grommets are also placed at the lowest drainage points of wings, ailerons, fuselage, and empennage components to provide complete drainage.

Plastic grommets (figure 3–12) are either in the shape of a thin, circular washer or are streamlined. Plastic grommets are doped to the fabric cover immediately after the surface tape is applied. Streamlined grommets usually are installed with the opening located toward the trailing edge of the surface.

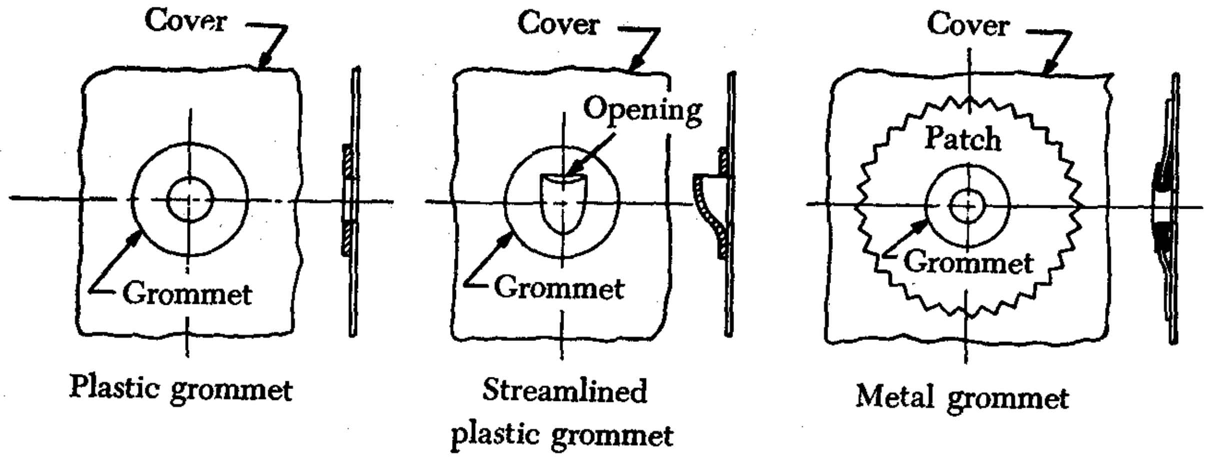


FIGURE 3–12. Typical grommets.

Brass and aluminum grommets, also shown in figure 3–12, are mounted on either circular or square fabric patches. The edges of the patch are pinked to provide better adhesion. The patch assembly is doped to the cover after the surface tape is applied.

Inspection doors and access holes are provided in all surfaces, whether fabric or metal covered. One way to provide these openings on fabric-covered surfaces is to dope a zipper-equipped patch in the desired place. Another inspection method for cloth or metal surfaces is to install a framework inside the wing to which a cover plate can be attached by screws. These frameworks are built into the structure wherever access or inspection holes are necessary.

REPAIR OF FABRIC COVERS

General

Repair fabric-covered surfaces so that the original strength and tautness are returned to the fabric. Repair all tears or punctures immediately to prevent the entry of moisture or foreign objects into the interior of the structure. Sewn and unsewn repairs are permitted. The type of repair technique to be used depends on the size and location of the damage as well as the never-exceed speed of the aircraft.

When re-covering or repairing control surface fabric, especially on high-performance airplanes, the repairs must not involve the addition of weight aft of the hinge line. The addition of weight disturbs the dynamic and static balance of the surface to a degree that will induce flutter.

Repair of Tears

Small cuts or tears are repaired by sewing the edges together and doping a pinked- or frayed-edge patch over the area. The baseball stitch is used in repairing tears. The type illustrated in figure 3–13 enables the damaged edges to be drawn to their original location, thus permitting a tighter repair to be made. The first stitch is started by inserting the needle from the underneath side. All remaining stitches are made by inserting the needle from the top instead of from the bottom so that the points for making the stitch can be more accurately located. The edges are sewn together using the proper thread. The last stitch is anchored with a modified seine knot. Stitches should not be more than 1/4 in. apart and should extend 1/4 in. into the untorn cover.

Cut two patches of sufficient size to cover the tear and extend at least 1-1/2 in. beyond the tear in all directions (figure 3–14). The fabric used should be at least as good as the original fabric. The edges of the patch should be either pinked or frayed about 1/4 in. on all sides. One patch is saturated with nitrate thinner or acetone and laid over the sewn tear to remove the old finish. The patch is occasionally moistened with a brush until all but the clear

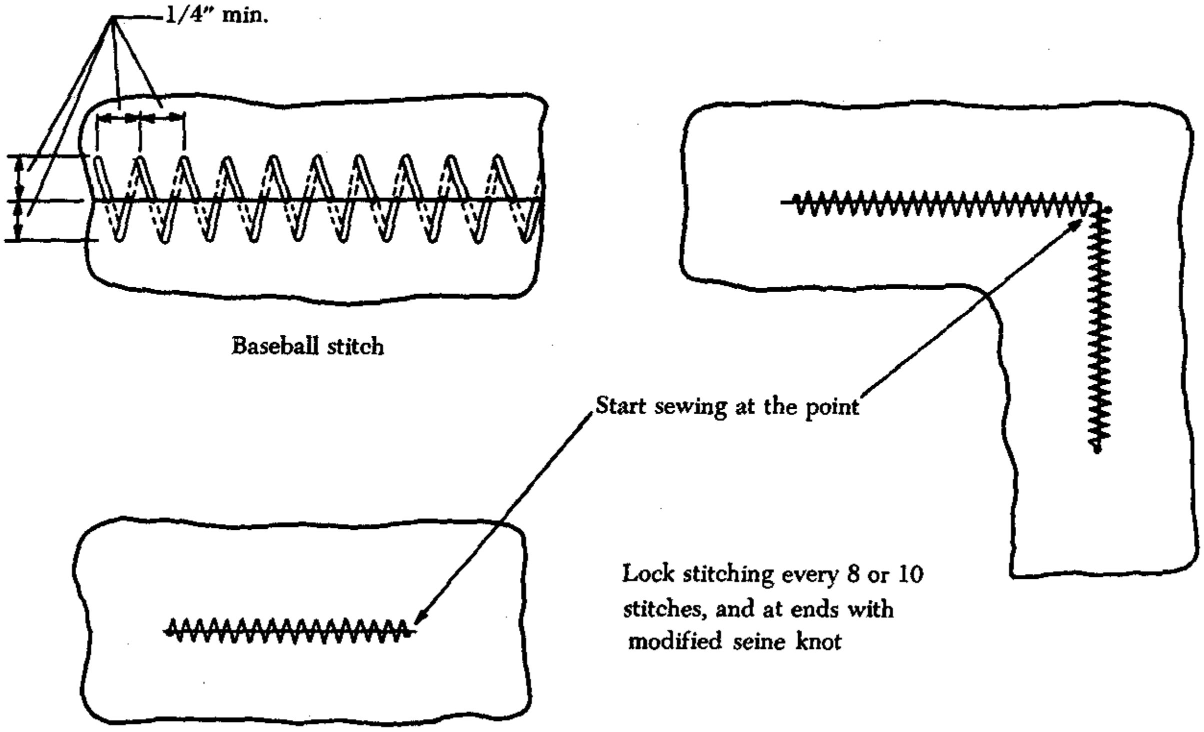


FIGURE 3–13. Repair of tears in fabric.

undercoats are soft enough to be removed with a putty knife. Since only the finish under the patch is removed, a neat, smooth repair can be made. A coat of clear tautening dope is applied to the second patch and to the area of the cover from which the finish has been removed. While still wet, this patch is applied to the cover and rubbed so it is smooth and free of air bubbles. Successive coats of clear, pigmented dope are applied until the patched surface has attained the same tension and appearance as the original surrounding surface.

Sewed Patch Repair

Damage to covers where the edges of the tear are tattered beyond joining or where a piece has been completely torn away is repaired by sewing a fabric patch into the damaged area and doping a surface patch over the sewed insert. A sewed-in repair patch may be used if the damage is not longer than 16 in. in any one direction.

The damaged area is trimmed in the form of a circle (figure 3–15) or oval-shaped opening. A fabric insert is cut large enough to extend 1/2 in. beyond the diameter of the opening. The 1/2-in. allowance is folded under as reinforcement. Before sewing, fasten the patch at several points with a few temporary stitches to aid in sewing the seams. The edges of the insert are sewed with a baseball stitch.

After the sewing is completed, clean the area of the old fabric to be doped as indicated for repair of tears and then dope the patch in the regular manner. Apply surface tape over any seams that have a second coat of dope. If the opening extends over or closer than 1 in. to a rib or other laced member, the patch should be cut to extend 3 in. beyond the member. After sewing has been completed, the patch should be laced to the rib over a new section of reinforcing tape. The old rib lacing and reinforcing tape should not be removed.

If the fabric covering is damaged at the trailing edge or part of it is torn away as shown in figure 3–16A, it can be repaired as follows. The damaged portion of the panel is removed, and a rectangular- or square-shaped opening is made as shown in figure 3–16B. A patch is cut of sufficient size to extend 3/4 in. beyond both sides and the bottom edge of the opening, and 1/2 in. beyond the top. The edges of the patch are reinforced by being folded under 1/2 in. before being sewed, and each corner is stretched and temporarily held in place with T-pins. Two sides and the trailing edge, as shown in figure 3–16C, are sewed to the old cover with the folded edge extending 1/4 in. beyond both

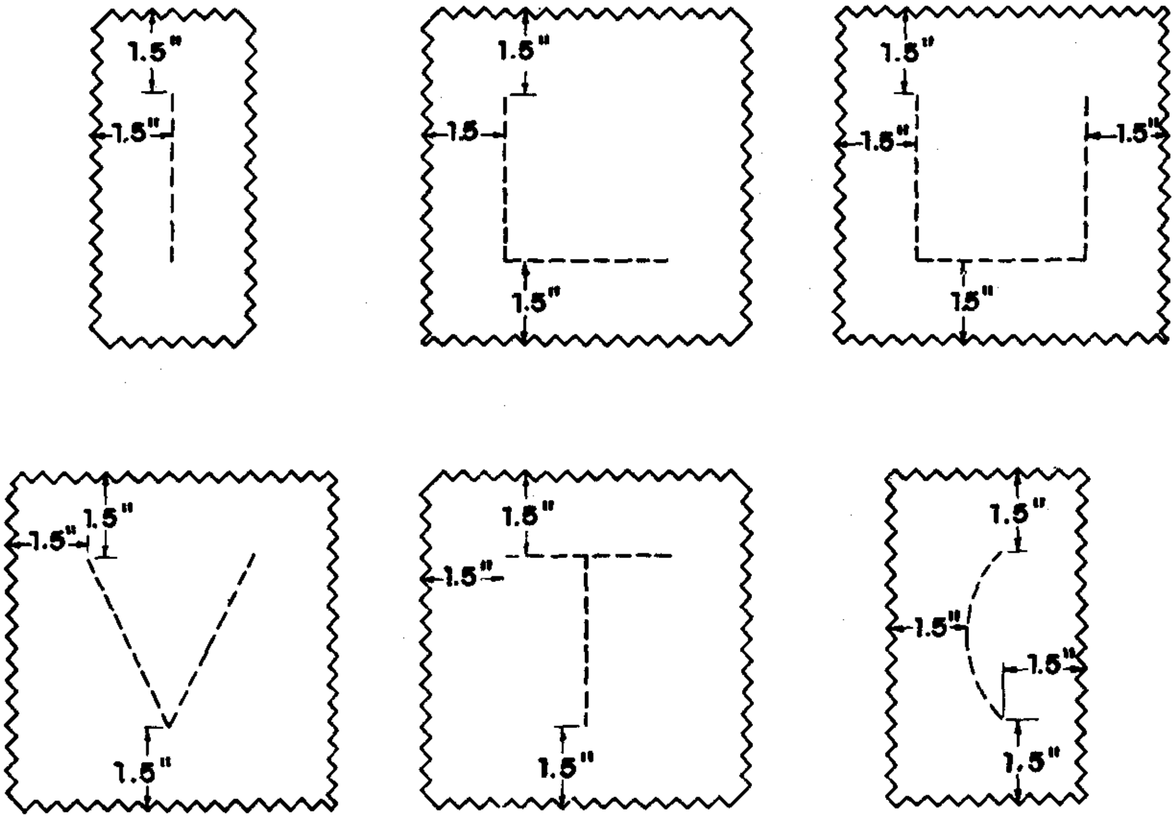


FIGURE 3–14. Patching over tears. Dash line represents a stitched tear.

ribs. The top of the opening is then sewed. Taping and doping, as shown in figure 3–16D, completes the repair.

Sewed-In Panel Repair

When the damaged area exceeds 16 in. in any direction, a new panel should be installed. Remove the surface tape from the ribs adjacent to the damaged area and from the trailing and leading edges of the section being repaired. Leave the old reinforcing tape in place.

Cut the old fabric along a line approximately 1 in. from the center of the ribs on the sides nearest to the damage, and continue the cuts to remove the damaged section completely. The old fabric should not be removed from the leading and trailing edges unless both upper and lower surfaces are being re-covered. Do not remove the reinforcing tape and lacing at the ribs.

Cut a patch to extend from the trailing edge up to and around the leading edge and back approximately to the front beam. The patch should extend approximately 3 in. beyond the ribs adjacent to the damage.

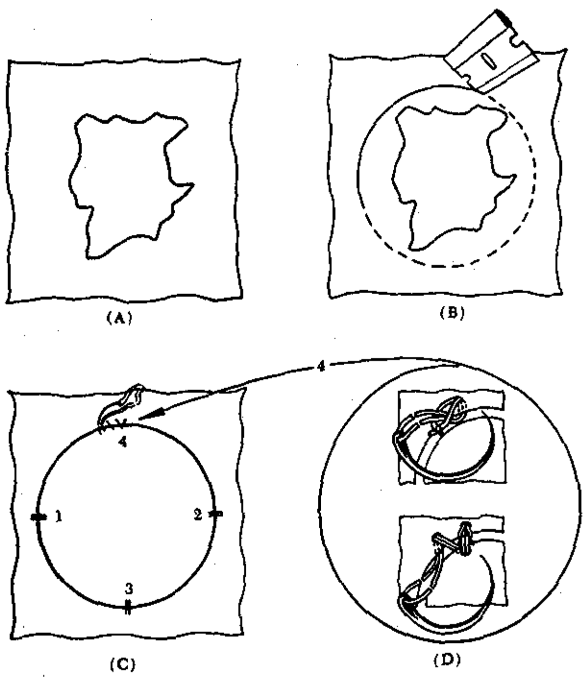


FIGURE 3–15. Sewed patch repair.

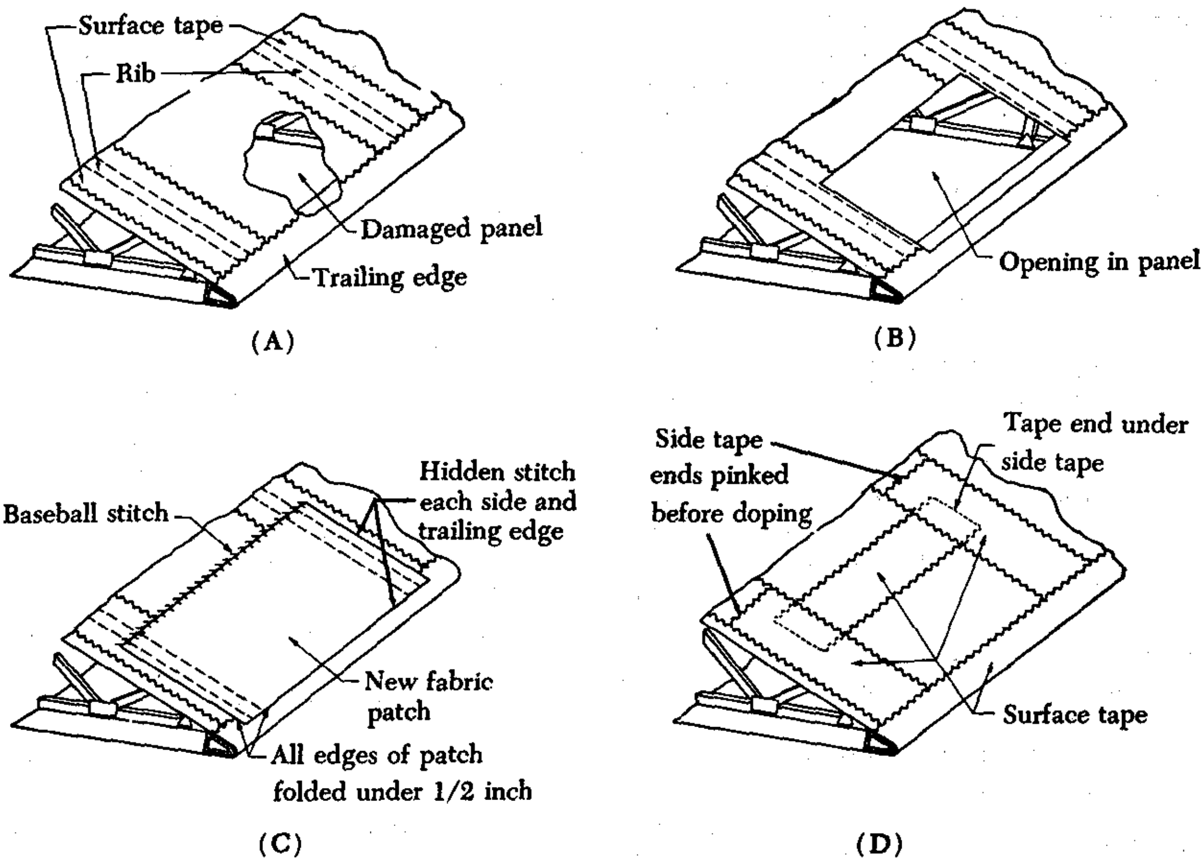


FIGURE 3-16. Repair of panel at trailing edge.

Clean the area of the old fabric to be covered by the patch, put the patch in place, stretch taut and pin. After the patch is pinned in place, fold under the trailing and leading edges of the patch 1/2 in. and sew to the old fabric. Fold the side edges under 1/2 in. and sew to the old cover. After completing the sewing, place reinforcing tape over the ribs under moderate tension and lace down (rib lace or stitch) to the ribs. Remove the temporary pinning.

Give the panel a coat of clear dope and allow to dry. Apply surface tape with the second coat of dope over the reinforcing tape and over the edges of the panel. Finish the doping using regular doping procedures.

This type of repair may be extended to cover both the upper and lower surfaces and to cover several rib bays if necessary. The panel must be laced to all ribs covered.

Unsewed (Doped-On) Fabric Repairs

Unsewed (doped-on) repairs may be made on all aircraft fabric-covered surfaces, provided the aircraft never-exceed speed is not greater than 150 m.p.h. A doped-on patch repair may be used if the damage does not exceed 16 in. in any direction. Cut out the damaged section, making a round or oval-shaped opening trimmed to a smooth contour. Use a grease solvent to clean the edges of the opening to be covered by the patch. Sand off the dope from the area around the patch or wash it off with a dope thinner. Support the fabric from underneath while sanding.

For holes up to 8 in. in size, make the fabric patch of sufficient size to provide a lap of at least 2 in. around the hole. For holes over 8 in. in size, make the overlap of the fabric around the hole at least one-fourth the hole diameter with a maximum lap limit of 4 in. If the hole extends over a rib or closer than the required overlap to a rib or other laced member, the patch should be extended at least 3 in. beyond the rib. In this case, after the edges of the patch have been doped in place and the dope has dried, the patch should be laced to the rib over a new section of reinforcing tape in the usual manner. The old rib lacing and reinforcing should not be removed. All patches should have pinked edges or, if smooth, should be finished with pinked-edge surface tape.

Doped-in Panel Repair

When the damage exceeds 16 in. in any direction, make the repair by doping in a new panel. This type of repair may be extended to cover both the upper and lower surfaces and to cover several rib bays if necessary. The panel should be laced to all ribs covered, and it should be doped or sewed as in the blanket method.

Remove the surface tape from the ribs adjacent to the damaged area and from the trailing and leading edges of the section being repaired. Leave the old reinforcing tape and lacing in place. Next cut the fabric along a line approximately 1 in. from the ribs on the sides nearest to the damage and continue cutting to remove the damaged section completely. The old fabric should not be removed from the leading and trailing edges unless both upper and lower surfaces are being re-covered.

Cut a patch to run around the trailing edge 1 in. and to extend from the trailing edge up to and around the leading edge and back approximately to the front beam. The patch should extend approximately 3 in. beyond the ribs adjacent to the damage. As an alternative attachment on metal or wood-covered leading edges, the patch may be lapped over the old fabric at least 4 in. at the nose of the leading edge, doped, and finished with at least 8 in. of pinked-edge surface tape.

Clean the area of the old fabric that is to be covered by the patch and apply a generous coat of dope to this area. Put the new panel in place, pull as taut as possible, and apply a coat of dope to the portion of the panel that overlaps the old fabric. After this coat has dried, apply a second coat of dope to the overlapped area and allow to dry.

Place reinforcing tape, under moderate tension, over the ribs and lace the fabric to the ribs.

Give the panel a coat of clear dope and allow to dry. Apply surface tape with the second coat of dope over the reinforcing tape and over the edges of the panel. Finish the doping process using the regular doping procedure.

REPLACING PANELS IN WING COVERS

Repairs to structural parts require opening of the fabric. The surface tape is removed from the damaged rib, the ribs on either side of the damaged rib, and along the leading and trailing edges where the fabric is to be cut. The rib lacing is removed from the damaged rib. The cover is cut along the top of the damaged rib and along the leading and trailing edges as shown in figure 3–17.

To close an opening of this size, the cut edges are joined over the rib, the leading edge, and the trailing edge with the baseball stitch and a new fabric panel is sewn over all the repaired area. The new panel extends between the adjacent ribs and from the trailing edge to the leading edge (figure 3–18). The new fabric is cut so that it can be folded under 1/2 in. and carried 1/4 in. beyond the adjacent ribs where it is sewed. The leading and trailing edges are folded and sewed in the same manner. After the panel has been sewed in place, new reinforcing tape is laced over the repaired rib. The new fabric is laced at each of the adjacent ribs without using any additional reinforcing tape. Finally, all surface tapes are replaced, and the new surface is finished to correspond to the original covering.

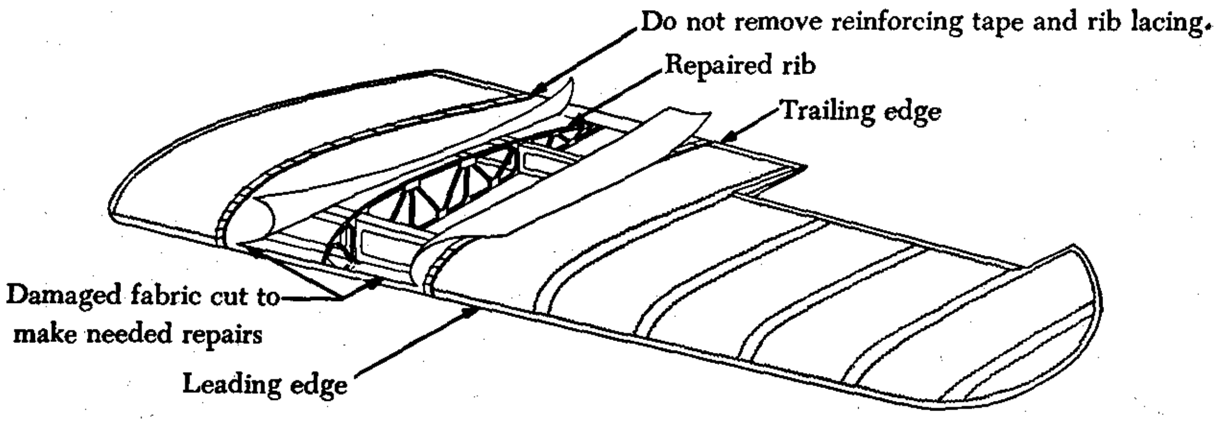


FIGURE 3–17. Opening cover for internal structural repair.

RE-COVERING AIRCRAFT SURFACE WITH GLASS CLOTH

Fiber glass fabrics are acceptable for re-covering or reinforcing an aircraft surface, provided the material meets the requirements of Military Specifications MIL–C–9084, MIL–Y–1140, and MIL–G–1140. The tensile strength of the glass cloth should be at least equivalent to the tensile strength of the fabric originally installed on the aircraft. The chemical finish of the glass cloth should be chemically compatible with the dope or resin to be used.

Either the blanket or envelope method of reinforcement should be used on treated fabrics that can be sewn. Untreated fabric that cannot be sewn may be applied in overlapping sections. The practices recommended for doped seams should be used. Where the glass cloth is applied only to the upper surface of the wings for hail protection, it should wrap around the trailing edge at least 1 in. and extend from the trailing edge up to and around the leading edge and back approximately to the front spar. Before starting the work, make certain that the bonding agents used will be satisfactory. Blistering or poor adhesion can occur when using bonding agents which are not chemically compatible with the present finish on the aircraft, or which have already deteriorated because of age. A simple means of determining this is to apply a small piece of the reinforcement cloth to the original cover, using the proposed finishing process. The test sample should be visually checked the next day for blistering or poor adhesion.

When butyrate dope is used to bond glass cloth, the finishing can be accomplished in the following manner:

(1) Thoroughly clean the surface and allow to dry. If the surface has been waxed or previously covered with other protective coatings, thoroughly remove at least the top finish coat. After placing the glass cloth on the surface, brush out smoothly and thoroughly with butyrate dope thinner and 10% (by volume) retarder.

(2) Apply a heavy coat of butyrate dope between all glass cloth overlaps. When dry, brush in butyrate rejuvenator and allow to set until the surface has again drawn tight.

(3) Install reinforcing tape and structural attachments (Class B) and dope on finishing tape (cotton is recommended); then brush in one coat of 50% thinner and 50% butyrate dope.

(4) Follow by conventional finishing schedules, which call for application of one or more coats of full-bodied clear butyrate dope, two spray coats of aluminum pigmented butyrate dope, light surface sanding, and two spray coats of pigmented butyrate dope.

When resin is used to bond the glass cloth, after surface cleaning, the finishing may be done in the following manner:

(1) Rejuvenate the doped surface. After placing the glass cloth on the surface, brush in thoroughly a coat of resin. Saturate overlapped areas thoroughly and allow to cure.

(2) Brush in a second coat of resin smoothly and evenly and allow to cure. The finished surface should not be considered completed until all the holes between the weave of the cloth are filled flush with resin.

(3) After water sanding, paint the surface with one coat of primer surfacer and finish as desired.

Install drain grommets and inspection holes as provided in the original cover.

When using glass fabric to reinforce movable control surfaces, check to ascertain that no change has been made in their static and dynamic balance.

CAUSES OF FABRIC DETERIORATION

Aircraft fabrics deteriorate more rapidly in areas of heavy industrialization than in areas that have cleaner air. The greatest single cause of aircraft fabric deterioration is sulfur dioxide. This toxic compound is present in variable amounts in the

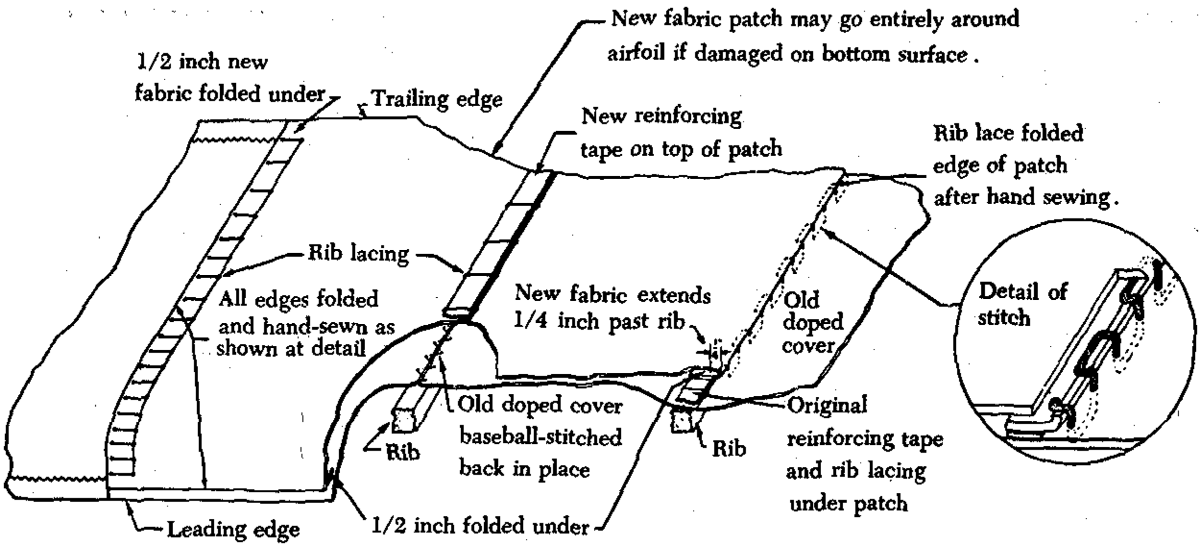


Figure 3–18. Method of replacing cover.

atmosphere. It occurs in large concentrations in industrial areas. Sulfur dioxide combines with oxygen, sunlight, and moisture to form sulfuric acid, which, readily attacks cotton fabrics. Linen fabrics are also affected, but to a lesser degree than cotton. Dacron fabric is far more resistant to sulfur dioxide and other chemicals than any other fabric except fiber glass fabric. Fiber glass fabric is not affected by moisture, mildew, chemicals, or most acids.

Mildew

Mildew spores attack fabrics when they are damp. All natural cellulose fibers provide nourishment for mildew growth when conditions are right. Mildew spores, also known as fungus or mold, can be controlled by using a fungus inhibitor. The inhibitor is usually mixed with dope and applied with the first coat of dope. Dope containing fungicides should not be sprayed because they contain poisons.

Re-covering should be done in dry, clean buildings. Damp, dirty buildings encourage mildew growth. The spores grow on damp rags, paper, etc., and are deposited directly on the fabric surfaces by any movement which stirs the air in the area. Spores are always present in the atmosphere in varying degrees and are induced into the airframe enclosures by air movement. An aircraft should be flown frequently to circulate dry air into the wings and fuselage so that moisture, which supports mildew, will not accumulate.

Acid Dopes and Thinners

The use of dopes or thinners whose acidity has increased beyond safe limits can cause rapid deterioration of aircraft fabrics. When dope is stored under extremes of heat or cold, chemical reactions increase the acidity beyond safe limits.

Stocks of Military dope compound are sold as surplus when periodic tests indicate that the dope has developed an acid content in excess of a safe value. Using surplus dope can lead to early fabric deterioration.

General-purpose thinners should not be used to thin aircraft dope. Such thinners are usually acidic and are not formulated for use with dope.

Insufficient Dope Film

A thin dope film does not provide sufficient protection of the fabric from the elements, and early deterioration of the fabric may result. Ultraviolet light, which is invisible, combines with oxygen to form an oxidizing agent that attacks organic materials. The ultraviolet rays can be screened by adding pigments to the dope film and by adequately covering the fabric with the dope. Aluminum powder usually is added to two of the dope coats to stop any ultraviolet light from reaching the fabric. Undoped fabric or fabric covering that is not protected by coats of aluminum-pigmented dope should not be exposed to sunlight for long periods.

Adequate protection of the fabric usually is achieved if the dope film hides the weave of the fabric, leaving a smooth surface. This cannot be determined by the number of coats of dope applied, but rather by the dope film thickness. This varies with application technique, temperature, dope consistency, and equipment.

Cracks in the dope film admit moisture and light, causing localized deterioration of the fabric.

Storage Conditions

It is generally assumed that a hangared aircraft is protected from fabric deterioration. However, premature deterioration can occur, especially on aircraft stored in an unheated hangar that has a dirt floor. During the day, sun shining on the roof raises the air temperature in the hangar. This warm air absorbs moisture from the ground. When the air cools, the absorbed moisture condenses and settles on the aircraft. Atmospheric pressure changes draw the damp air into the airframe enclosures. These conditions provide an ideal situation for promoting mildew growth.

When storing fabric-covered aircraft, all openings large enough for rodents to enter should be taped. Uric acid from mice can rot fabric. It can also corrode metal parts, such as ribs, spars, and fittings.

CHECKING CONDITION OF DOPED FABRIC

The condition of doped fabric should be checked at intervals sufficient to determine that the strength of the fabric has not deteriorated to the point where airworthiness of the aircraft is affected.

The areas selected for test should be those known to deteriorate most rapidly. The top surfaces generally deteriorate more rapidly than the side or bottom surfaces. When contrasting colors are used on an aircraft, the fabric will deteriorate more rapidly under the darker colors. The dark colors absorb more heat than the lighter colors. The warmer inner surface of the fabric under the dark color absorbs more moisture from the air inside the wing or fuselage. When the surface cools, this moisture condenses and the fabric under the dark area becomes moist and promotes mildew growth in a localized area. When checking cloth fabric that has been reinforced by applying fiber glass, peel back the glass cloth in the areas to be tested. Test the underlying cloth in the conventional manner.

Checking fabric surfaces is made easier by using a fabric punch tester. There are several acceptable fabric punch testers on the market; one such tester incorporates a penetrating cone (figure 3–19). Fabric punch testers are designed for use on the dope-finished-fabric surface of the aircraft and provide only a general indication of the degree of deterioration in the strength of the fabric covering. Their advantage is that they may be used easily and quickly to test the fabric surfaces without cutting samples from the airplane's fabric. If a fabric punch tester indicates that the aircraft fabric strength is marginal, a laboratory test should be performed to determine the actual fabric strength.

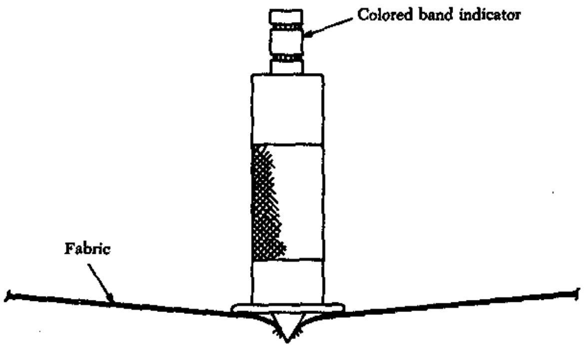


FIGURE 3–19. Fabric punch tester.

When using a punch tester similar to the one illustrated in figure 3–19, place the tip on the doped fabric. With the tester held perpendicular to the surface, apply pressure with a slight rotary action until the flange of the tester contacts the fabric. The condition of the fabric is indicated by a color-banded plunger that projects from the top of the tester. The last exposed band is compared to a chart supplied by the manufacturer of the tester to determine fabric condition.

The test should be repeated at various positions on the fabric. The lowest reading obtained, other than on an isolated reparable area, should be considered representative of the fabric condition as a whole. Fabrics that test just within the acceptable range should be checked frequently thereafter to ensure continued serviceability.

The punch tester makes only a small hole (approximately 1/2-in. diameter) or a depression in the fabric that can be repaired quickly by doping on a 2-in. or 3-in. patch.

TESTING FABRIC COVERING

Tensile Testing of Undoped Fabric

Tensile testing of fabric is a practical means of

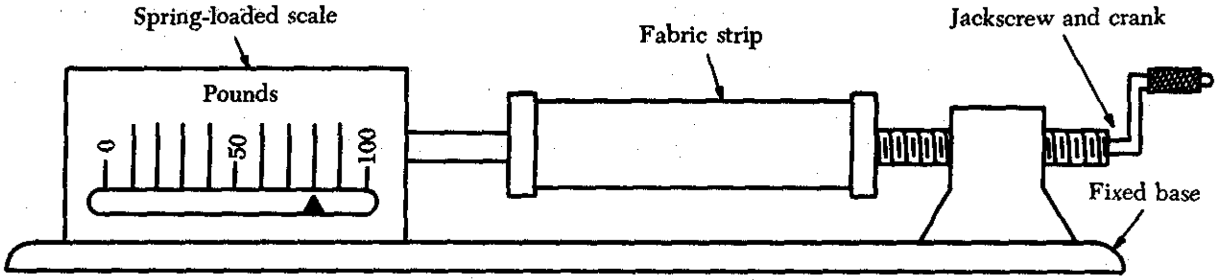


FIGURE 3–20. Fabric tensile tester.

determining whether a fabric covering has deteriorated to the point where re-covering is necessary. Figure 3–20 illustrates a typical fabric tensile tester.

A sample of the undoped fabric to be tested is cut to exactly 1-1/2-in. wide and to a sufficient length (usually 6 in.) to allow insertion in the fabric tester. Usually, each edge of the strip is frayed 1/4 in., reducing the woven width to 1 in. The ends of the fabric strip are fastened securely in the clamps of the tester. As the crank of the tester is turned, the threaded jackscrew is backed out, thus gradually increasing the tension (pull) on the fabric against the resistance of the spring-loaded scale until the fabric strip breaks. The scale reading, taken at the moment the fabric strip breaks, indicates the strength of the fabric in pounds per inch.

Fabric specimens must be tensile tested in the undoped condition. Use acetone dope thinner or other appropriate thinning agents to remove the finishing materials from the test specimen.

STRENGTH CRITERIA FOR AIRCRAFT FABRIC

Present minimum strength values for new aircraft fabric covering are provided in figure 3–1.

The maximum permissible deterioration for used aircraft fabric, based on a large number of tests, is 30%. Fabric that has less than 70% of the originally required tensile strength is not considered airworthy. Figure 3–1 contains the minimum tensile strength values for deteriorated fabric tested in the undoped condition.

Some light aircraft operators use the Grade A type fabric, but are only required to use intermediate grade fabric. In this case, the Grade A material is still considered airworthy, provided it has not deteriorated, as tested in the undoped condition, below 46 pounds, *i.e.*, 70% of the originally required tensile strength value for new intermediate fabric.

DOPES AND DOPING

To tighten fabric covering and to make it airtight and watertight, brush or spray the cloth with dope. A tight fabric cover is essential to securing and holding the cross-sectional shape of the airfoil to the form given it by the ribs. This dope also protects the fabric from deterioration by weather or sunlight and, when polished, imparts a smooth surface to the fabric and reduces skin friction. Dopes must be applied under ideal conditions to obtain satisfactory and consistent results. A clean, fresh, dry atmosphere with a temperature above 70° F. and a relative humidity below 60%, combined with good ventilation, is necessary in the dope room. The dope must be of the proper consistency and be applied uniformly over the entire surface.

Dopes will deteriorate seriously if stored in too warm a place for a long period. The temperature should not exceed 60° F. for long-time storage and must not exceed 80° F. for periods up to 4 months. Precautions against fire should be taken wherever dope is stored or used because of its flammable nature. Dope and paint rooms that are not located in a separate building should be isolated from the rest of the building by metal partitions and fireproof doors.

As stated previously, the most desirable condition in a dope room is a temperature above 70° F. and a relative humidity below 60%. At lower temperatures the dope will not flow freely without the addition of excessive thinners. The relative humidity can be lowered by raising the temperature if the dope shop is not equipped with humidity control. To condition fabric surfaces to the desired temperature and moisture conditions, allow them to stand about 4 hrs. in the dope room after covering and prior to doping.

The number of coats of dope applied to a fabric surface depends on the finish desired. It is customary to apply two to four coats of clear dope, followed by two coats of pigmented dope. Sufficient clear dope should be applied to increase the weight of the fabric by 2.25 to 2.50 oz./sq. yd. The clear-dope film should weigh this amount after drying for 72 hrs. With fabric weighing 4 oz., the total weight of fabric and dope is approximately 9.5 oz./sq. yd.

Pigmented dopes must be applied over the clear dopes to protect the fabric from the sunlight. Sufficient pigment must be added to the dope to form an opaque surface. Pigmented dopes consist of the properly colored pigment added to the clear dope. When an aluminum finish is desired, 1 gal. of the clear nitrocellulose dope is mixed with 12 oz. of aluminum powder and an equal additional amount of glycol sebacate plasticizer. Sufficient thinner is then added so that two coats of this dope will give a film weight of about 2 oz./sq. yd.

Panels should be doped in a horizontal position, whenever possible, to prevent the dope from running to the bottom of the panel. Hand brush the first coat of dope and work it uniformly into the fabric. A minimum of 30 min. under good atmospheric conditions should be allowed for drying between coats. Surface tape and patches should be applied just prior to the second coat of dope. This second coat should also be brushed on as smoothly as possible. A third and fourth coat of clear dope can be applied by either brushing or spraying. These coats of clear dope provide a taut and rigid surface to the fabric covering. If desired, this surface may be smoothed by lightly rubbing with number 280 or 320 wet or dry sandpaper, or a similar abrasive. When being rubbed, all surfaces should be electrically grounded to dissipate static electricity. The doping is completed by spraying two or more coats of the properly colored pigmented dope on the surface.

Under certain unfavorable atmospheric conditions, a freshly doped surface will blush. Blushing is caused by the precipitation of cellulose ester, which is caused largely by a high rate of evaporation and/or high humidity. High temperatures or currents of air blowing over the work increase the evaporation rate and increase blushing tendencies. Blushing seriously reduces the strength of the dope film and the necessary precautions should be taken to guard against blushing. When a doped surface blushes, it becomes dull in spots, or white in extreme cases.

The surface under the doped fabric must be protected to prevent the dope from "lifting" the paint on the surface. A common method is to apply dope-proof paint or zinc chromate primer over all parts of the surface that come in contact with doped fabric. Another excellent method is to cover this surface with aluminum foil 0.0005 in. thick. This foil is glued to the surface and prevents the penetration of dope. It is applied over the regular finish. Other materials, such as a cellophane tape, have also been used successfully in place of aluminum foil.

DOPE MATERIALS

Aircraft dope is any liquid applied to a fabric surface to produce tautness by shrinkage, to increase strength, to protect the fabric, to waterproof, and to make the fabric airtight. Aircraft dopes are also used extensively in the repair and rejuvenation of aircraft fabric surfaces.

Aircraft dope is technically a colloidal solution of cellulose acetate butyrate or cellulose nitrate. If nitric acid was used in the chemical manufacturing of the dope, it is known as cellulose nitrate dope. If acetic and butyric acids were used, the dope is known as cellulose acetate butyrate dope.

Cellulose-Nitrate Dope

Nitrocellulose dope is a solution of nitrocellulose and a plasticizer, such as glycol sebacate, ethyl acetate, butyl acetate, or butyl alcohol, or toluene. The nitrocellulose base is made by treating cotton in nitric acid. The plasticizer aids in producing a flexible film. Both the plasticizer and the solvents are responsible for the tautening action of dope. Thinners such as benzol or ethyl alcohol are sometimes added to the dope to obtain the proper consistency. These thinners evaporate with the volatile solvents.

Nitrate dope flows more freely and is more easily applied to fabric than butyrate dope. It burns readily and rapidly and is difficult to extenguish, whereas butyrate dope burns slowly and is easily extinguished. The tautening (shrinking) effect of nitrate is not quite so great as that of butyrate, but it is sufficient to tighten the fabric the desired amount.

Cellulose-Acetate-Butyrate Dope

This type of dope is composed of cellulose acetate butyrate and a plasticizer, triphenyl phosphate, which are nonvolatile when mixed with ethyl acetate, butyl acetate, diacetone alcohol or methyl ethyl ketone, all of which are volatile.

Butyrate dope has a greater tautening effect on fabric and is more fire resistant than nitrate dope.

The solvents of butyrate dope are more penetrating than those of nitrate dope, and butyrate dope can be applied successfully over dried nitrate dope on a fabric surface.

Both the cellulose nitrate and cellulose acetate butyrate dopes, without the addition of color pigments, are a clear, transparent solution. Both are used on aircraft fabric covering to shrink and tighten the fabric to a drum-like surface, to impregnate and fill the fabric-mesh, and to waterproof, airproof, strengthen, and preserve the fabric.

Pigments of the desired color may be added to the final two or three coats of dope applied to the fabric to attain the desired color and trim on the aircraft.

ALUMINUM-PIGMENTED DOPES

When at leat two or more coats of aluminum-pigmented dope (brushed or sprayed) have been applied over the first two or three coats of clear dope after they have dried and have been sanded, a thin film of aluminum is formed over the fabric and the undercoats of clear dope. This aluminum film insulates the fabric from the sun's heat and reflects the heat and ultraviolet rays away from the fabric surfaces of the aircraft.

Aluminum-pigmented dopes may be purchased already mixed and ready for application by brush or spray. However, it is often more economical and desirable to mix the powdered aluminum into the clear dope in the shop.

The aluminum for mixing into the clear dope may be obtained in either the powdered form or the paste form. In the powdered form it is nothing more than finely ground (pulverized) aluminum metal. In thc paste form the powdered aluminum metal has been mixed with an adhesive agent to form a putty-like paste.

Recommended mixing proportions are 1-1/2 lbs. of aluminum powder to 5 gal. of clear dope, or 1-3/4 lbs. of aluminum paste to 5 gal. of clear dope. First, thoroughly mix and dissolve the powder or paste in a small amount of alcohol thinner and then add to the clear dope.

TEMPERATURE AND HUMIDITY EFFECTS ON DOPE

The successful application of dope finishes on fabric depends on many things, including the method of application, temperature, humidity, correct mixture of anti-blush reducers and thinners, sanding, and preparation of the fabric. In addition to the special methods necessary in the application of dope, further precautions are required in the handling, storage, and use of dope because it is highly flammable and its fumes are harmful if breathed in excess. For the best and safest results, doping is usually done in a special dope room where many of these factors can be controlled.

Cold Effects on Dope

In cold weather, dopes left in unheated rooms or outside become quite viscous (thick). Cold dopes should be kept in a warm room between 75° F. and 80° F. at least 24 hrs. before being used. Dope in large drum containers (55 gal.) will require 48 hrs. to reach this temperature. Cold dopes will pull and rope under the brush and, if thinned sufficiently to spray or brush, will use extra thinner needlessly and will lack body when the thinner evaporates.

COMMON TROUBLES IN DOPE APPLICATION

Bubbles and Blisters

A heavy coat of lacquer applied over a doped surface that is not thoroughly dry will tend to form bubbles. To prevent this condition, allow the surface to dry for 10 to 12 hrs. Bubbles may be removed by washing the surface with dope thinner until smooth, allowing the surface to dry, and then sanding before refinishing. Blisters are caused by dope dripping through to the opposite fabric during application of the priming coat, as a result of excessive brushing over spars, ribs, or other parts. Dope may also seep through fittings, inspection openings, or patches, and form blisters. Extreme care should be taken to avoid blisters inasmuch as they can be removed only by cutting the fabric at the blister, and patching.

Slack Panels

Slack panels are caused by loose application of the fabric, or the fabric may have been applied with proper tension but permitted to remain undoped for too long a period, thus losing its tension. Fabric slackened by remaining undoped may be tightened by the application of acetone if it is applied as soon as the slackening is noticeable.

Extremes of temperature or humidity may cause dope to dry in such a condition that the fabric becomes slack. This can be remedied by spraying on another coat of dope containing either a slow dryer, such as butyl alcohol, or a rapid dryer, such as acetone, as conditions may require.

Inconsistent Coloring

Inconsistent coloring of enamels, paints, and pigmented dope, is caused by the pigments settling to the bottom of the container, thus depriving the upper portion of the vehicle of its proper percentage of pigment. If shaking the container does not distribute the pigment satisfactorily, a broad paddle or an agitator should be used to stir the mixture thoroughly.

Pinholes

Pinholes in the dope film can be caused by the temperature of the dope room being too high, by not brushing the priming coat well into fabric to seal it completely, by a heavy spray coat of a mixture containing too much thinner, or by water, oil, or dirt in the air supply of the spray gun.

Blushing

Blushing in dopes or lacquers is common in humid weather. This condition in cellulose nitrate and cellulose acetate dopes is caused by rapid evaporation of thinners and solvents. The evaporation lowers the temperature on the surface of the freshly doped fabric, causing condensation of moisture from the atmosphere. This moisture on the surface of the wet dope or lacquer precipitates the cellulose nitrate or cellulose acetate out of solution, thus giving the thick milky-white appearance known as blush. Of course, such a decomposed finish is of no value either in tautening or protecting the surface for any period of time. Therefore, the blush must be eliminated if the finish is to endure.

The common causes of blushing are:

(1) Temperature too low.
(2) Relative humidity too high.
(3) Drafts over freshly doped surface.
(4) Use of acetone as a thinner instead of nitrate thinner.

If causes (1) and (2) cannot be corrected, blushing may be avoided by adding butyl alcohol to the dope in sufficient quantity to correct the condition. Dope films that have blushed may be restored by applying another coat of dope, thinned with butyl alcohol, over the blushed film. This coat will dissolve the precipitation on the previous coat. If an additional coat is not desired, the blushed film may be removed by saturating a rag with butyl alcohol and rubbing it rapidly and lightly over the blushed film. If butyl alcohol does not remove the blushing, acetone may be applied in the same manner to accomplish this purpose.

Brittleness

Brittleness is caused by applying the fabric too tightly or by the aging of the doped surface. Overtight panels may be loosened by spraying a 50% solution of fast-evaporating solvent (acetone) and dope over the surface to soak into the dope layers, allowing the fabric to slacken. If the age of the doped surface causes brittleness, the only remedy is to re-cover the structure.

Peeling

Peeling is caused by failure to remove moisture, oil, or grease from the fabric before the surface is coated. Fabric areas so affected should be treated with acetone before the priming coat is applied.

Runs and Sags

Runs and sags in the finish are caused either by applying the dope too heavily or by allowing the dope to run over the sides and ends of the surface. Immediately after a surface is finished, the opposite and adjacent surfaces should be inspected for sags and runs.

TECHNIQUE OF APPLICATION

Apply the first two coats of dope by brush, spread on the surface as uniformly as possible, and thoroughly work into the fabric. Be careful not to work the dope through the fabric so that an excessive film is formed on the reverse side. The first coat should produce a thorough and uniform wetting of the fabric. To do so, work the dope with the warp and the fill threads for three or four brush strokes and stroke away any excess material to avoid piling up or dripping. Apply succeeding brush or spray coats with only sufficient brushing to spread the dope smoothly and evenly.

When doping fabric over plywood or metal-covered leading edges, care should be taken to ensure that an adequate bond is obtained between the fabric and the leading edge. Care should also be taken when using predoped fabric to use a thinned dope to obtain a good bond between the fabric and the leading edge of wings.

Applying Surface Tape and Reinforcing Patches

Apply surface tape and reinforcing patches with the second coat of dope. Apply surface tape over all rib lacing and all other points of the structure where tape reinforcements are required.

Installation of Drain Grommets

With the second coat of dope, install drain grommets on the underside of airfoils at the trailing edge and as close to the rib as practicable. On fuselages, install drain grommets at the center of the underside in each fuselage bay, located to ensure the best possible drainage. Special shielded grommets, sometimes called marine or suction grommets, are recommended for seaplanes to prevent the entry of spray. Also use this type of grommet on landplanes in the part of the structure that is subject to splash from the landing gear when operating from wet and muddy fields. Plastic type grommets are doped directly to the covering. Where brass grommets are used, mount them on fabric patches and then dope them to the covering. After the doping scheme is completed, open the drainholes by cutting out the fabric with a small-bladed knife. Do not open drain grommets by punching.

Use of Fungicidal Dopes

Fungicidal dope normally is used as the first coat for fabrics to prevent rotting. While it may be more advisable to purchase dope in which fungicide has already been incorporated, it is feasible to mix the fungicide with dope. Military Specification MIL–D–7850 requires that cellulose acetate butyrate dope incorporate a fungicide for the first coat used on aircraft. The fungicide designated in this specification is zinc dimethyldithiocarbonate, which forms a suspension with the dope. This material is a fine powder, and if it is mixed with the dope, it should be made into a paste, using dope, and then diluted to the proper consistency according to the manufacturer's instructions. It is not practicable to mix the powder with a large quantity of dope.

Copper naphtonate is also used as a fungicide and forms a solution with dope. However, this material has a tendency to bleed out, especially on light-colored fabric. It is considered satisfactory from a fungicidal standpoint.

The first coat of fungicidal dope should be applied extremely thin so that the dope can thoroughly saturate both sides of the fabric. Once the fabric is thoroughly saturated, subsequent coats may be applied at any satisfactory working consistency.

NUMBER OF COATS REQUIRED

Regulations require that the total number of coats of dope should be not less than that necessary to result in a taut and well-filled finish job. A guide for finishing fabric-covered aircraft is:

(1) Two coats of clear dope, brushed on and sanded after the second coat. To prevent damaging the rib stitch lacing cords and fabric, do not sand heavily over the center portion of pinked tape over ribs and spars.

(2) One coat of clear dope, either brushed or sprayed on, and sanded.

(3) Two coats of aluminum-pigmented dope, brushed or sprayed on, and sanded after each coat.

(4) Three coats of pigmented dope (the color desired), sanded and rubbed to give a smooth glossy finish when completed.